A Framework for Optimal Grasping of Deformable Objects

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Grasping mechanisms (*grippers*) are used for a wide range of applications including fixturing arrangements, industrial, agricultural, and service robotics for medical and home use. The gripper must immobilize the object it is manipulating, while applying the minimal necessary gripping force, in order to prevent the grasped object's bruising or the gripper being overly strenuous. This requires development of a grasp model.

The grasp model includes kinematic, dynamic and contact models. The kinematic model defines the system's mechanical constraints, the dynamic model defines the dynamic reactions of the system's elements, and the contact model defines the coupling between the force and torque reactions between the object and the gripper to their deformations.

All grasp models are greatly dependent on the system's parameters, such as the number of contact points, the object's geometry, the gripper's structure, the desired object's manipulation, and the mechanical properties of the object and gripper. Some of the parameters are easier to define, such as the object's desired manipulation or the geometries of the object and the gripper. Other parameters, like the object's and the fingertip's mechanical properties and an appropriate contact model, are more difficult to define.

Many contact models were developed in order to assess the reactions. They vary from considering rigid components and point fingertips with no friction at the contact point, to soft finger models - assuming elasticity or compliant components, which imply a contact area with a spatial distributed force and torque. Note that the contact's location is referred as "contact point", although geometrically it is an area in some of the discussed models.

This paper presents a framework to analyze the object's geometry and the defined contact points in order to provide the set of forces and torques that can be applied to the grasped object, without losing equilibrium. Grasp synthesis and grasp planning, are usually performed as a search in the system's configuration space, which is constrained by the selection of a specific gripper. The search process maps the configuration space, and assesses the grasp quality at each point, by the defined grasping quality criteria. This work presents a different approach. Instead of constraining the grasp to a specific gripper, the external set forces and torques that can be applied to the object are determined; the synthesis provides an optimal set of positions for 'n' contact points. These positions are optimal in the sense of minimizing reaction force and torque at each contact point.

In section 2 the main issues in grasp modeling, analysis and synthesis are reviewed. Its followed sections 3 present the main contribution of this paper, which is the optimal grasp synthesis methodology - described step-by-step by its layers. Finely, section 4 describes the model analysis, performed by computer simulation and validate by performed experiments.